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BY

AUGUSTUS H. GILL, PH. D.

PROFESSOR OF TECHNICAL ANALYSIS, MASSACHUSETTS INSTITUTE
OF TECHNOLOGY, CAMBRIDGE, MASS.

Contents

Introduction

Oils are nearly colorless, yellowish, brownish red, or black liquids having a peculiar fluidity or "body." They are thicker than water on which they usually float, and are neither acid nor alkaline in character.

According to their origin, they are divided into two great classes:

(1) Mineral oils, coming from the earth.

(2) Organic oils, the product of animal or vegetable life.

The mineral oils are similarly divided into two classes: those of paraffin base and those of asphaltic base. The former are more extensively used as lubricants, although the use of the latter for this purpose is increasing. Certain thick asphaltic oils when heated, and a current of compressed air blown through them, change into asphalt, "oil," or "artificial asphalt," whereas the paraffin oils remain practically unchanged.

Organic oils are obtained from the seeds of plants or the fat of animals, and are also divided into two classes: fixed or fatty oils, and essential or volatile oils. The fixed oils, like lard or olive, leave a permanent stain on cloth or paper, while the spot made by volatile oils like turpentine or clove, evaporates completely on exposure to the air.

The fixed or fatty oils are subdivided into three groups: the drying, the semi-drying, and the non-drying oils. A drying oil hardens and soon forms a skin on exposure to the air, by the absorption of oxygen, as shown with linseed oil. The semi-drying oil tends to the same condition, but naturally contains too many non-drying compounds to permit it. Cottonseed or corn oil is an example of this, thickening somewhat on exposure to the air. The non-drying oils, such as olive or lard, as their name denotes, change but little even on very long exposure.

The volatile oils are the substances that impart the characteristic odor to plants and animals. They are interesting to us only as they serve to mask some familiar or disagreeable odor of an oil in a lubricating compound.

Having defined the various oils, it is interesting to see how these differences are accounted for and learn something more about their properties.

The mineral oils are composed of hydrocarbons, that is, liquids made up of hydrogen and carbon. Hydrogen (H) is a gas used in filling balloons, while carbon (C) is familiar to us in coal, coke, black lead and the diamond. When chemically bound to hydrogen, it makes natural gas (mainly CH_4, the simplest hydrocarbon), gasoline (C_6H_{14}), kerosene, spindle oil and all the various mineral lubricating oils, and finally solid paraffin.

The symbols or formulas just used (CH_4, C_6H_{14}) are in the first place abbreviations; but they mean more than the ferr. sulph. (ferrous sulphate) and pot. nitr. (potassium nitrate) of the apothecary; they show by a small figure (4, 6, 14) written after the element and below the line, the number of atoms or smallest parts of each element in a molecule or smallest part of a substance.

Thus CH_4 means in marsh gas (methane) that we find 1 atom of carbon and 4 atoms of hydrogen, or since every atom of carbon weighs 12 units and hydrogen, 1, there are 12 parts, 75 per cent., by weight of carbon in a molecule of marsh gas and 4 parts, 25 per cent. by weight of hydrogen. So with C_6H_{14}, the symbol means there are 6 atoms of carbon and 14 atoms of hydrogen combined to make a molecule of hexane; or there are 72/86th of 84 per cent. carbon and 14/86ths or 16 per cent. hydrogen in the compound. ᐧ

So it is with every chemical formula. If we let the number of carbon atoms be represented by n, we shall find that hydrogen atoms can be represented by $2n + 2$; this is the general formula of the paraffin series.

Besides this we have several other series—the olefine CnH_2n, members of which are also found in lubricating oils, CnH_2n-2; the acetylene series, CnH_2n-6; the aromatic series, and others, the basis of many of the perfumes, dyes and drugs. Toluene (toluol) one of its members, is used to make T.N.T. tri-nitro-toluene or toluol.

These hydrocarbons, particularly the paraffins, are neutral, inert, inactive compounds, the word "neutral" meaning "without affinity." They are insoluble in water and cannot be saponified; this is why it is that spots of loom oil are so

difficult to remove. Some of them in thin layers even tend to gum or resinify, making their removal still harder. All that soaps or alkalis do to them is to emulsify or split them up into exceedingly small globules and envelop them with a film of soap, preventing them from sticking to the fabric or each other, in which condition they can be washed off.

Organic oils, like the preceding, are made up of hydrogen and carbon and also oxygen. They are compounds of glycerine and fatty acids—organic salts of organic acids. By the term salt is meant a compound formed by the union of an acid and a base. Acids are contained in vinegar, in sour milk and fruits, and "soldering acid": they have a sour taste and turn vegetable blues red.

Bases or alkalis are exactly opposite in character to the acids, they are familiar to us in slaked lime, "household ammonia" and lye. They have a biting taste and a "soapy feel," actually dissolving the skin, and turn vegetable reds blue. The base in the case of these oils is glycerine $C_3H_5(OH)_3$. The acid may be one of a number of fatty acids, stearic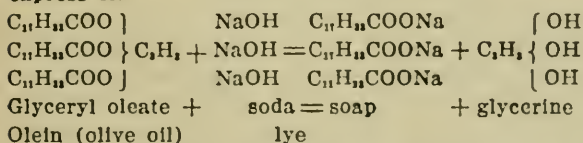 $C_{17}H_{35}COOH$, or oleic $C_{17}H_{33}COOH$; in the animal fats and oils—olive or neatsfoot for example, it is largely olein, having the formula

$$\left. \begin{array}{l} C_{17}H_{33}COO \\ C_{17}H_{33}COO \\ C_{17}H_{33}COO \end{array} \right\} C_3H_5$$
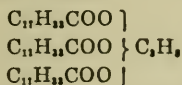
which is oleate of glyceryl. When these oils are made into soap, glycerine is always formed, and, as is well known, is a by-product of the soap factories. An idea of what takes place may be gained from the expression:

Oil + lye gives soap + glycerine, or as the chemist would express it:

$$\begin{array}{llll} \left. \begin{array}{l} C_{17}H_{33}COO \\ C_{17}H_{33}COO \\ C_{17}H_{33}COO \end{array} \right\} C_3H_5 + & \begin{array}{l} NaOH \\ NaOH \\ NaOH \end{array} = & \begin{array}{l} C_{17}H_{33}COONa \\ C_{17}H_{33}COONa \\ C_{17}H_{33}COONa \end{array} + C_3H_5 \left\{ \begin{array}{l} OH \\ OH \\ OH \end{array} \right. \end{array}$$

Glyceryl oleate +   soda = soap   + glycerine
Olein (olive oil)   lye

The reaction, as it is called, pictures the process known as saponification, and explains the washing out of wool oils from fabrics, the soap formed being dissolved in water.

Inasmuch as machine oils, usually hydrocarbon oils, *are unsaponifiable,* it explains why these are so difficult to remove.

Many experiments have been made, and much time consumed in attempts to saponify hydrocarbon oils, but it is impossible, and the explanation just given shows why it is. The most that has been accomplished, is to mix the soap and mineral oil together, the soap emulsifying the latter and enabling it to be partially washed out.

Mineral Oils.

Several theories have been proposed as to the origin of petroleum. One is that it was formed from the flowerless plants and simple animals at about the same time and in a
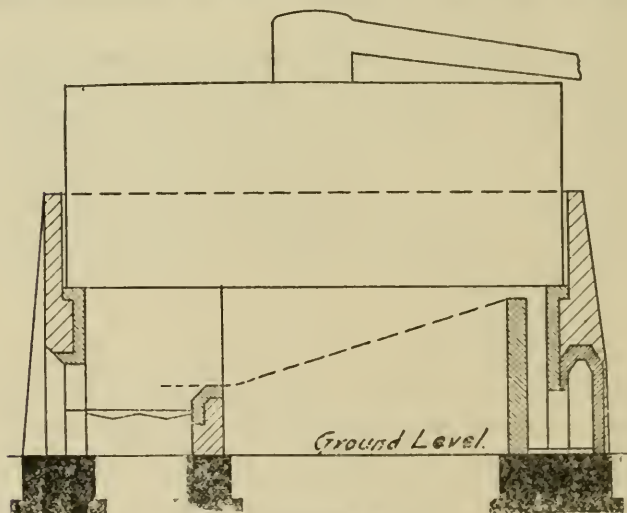
Fig. 1—PETROLEUM STILL.

similar manner as was coal. Another that it was produced by the natural distillation of the fat of the fish that were so abundant just subsequent to the coal period. Professor Engler has substantiated this theory by distilling half a ton of menhaden oil at a pressure of 150 pounds and obtaining a product resembling crude petroleum, from which, by distillation, a good illuminating oil was prepared.

Petroleum (rock oil) is found in many localities, of which those in North America, Canada, Mexico and Russia are the more important. It is obtained by drilling a well, like an ar-

tesian well, until the oil-sands are reached, usually at a depth of 1,800 or 2,000 feet, whence the oil gushes for a time and afterward requires to be pumped.

It finds its way by pipe lines and storage tanks into the still, Figs. 1 and 2. This still resembles a horizontal tubular boiler 42 feet long x 15 feet in diameter, holding about 50,-000 gallons. This is heated at the end or side, using coal or oil as fuel. The vapors formed by the heat pass out by domes and goosenecks to the condenser, Fig. 3, which are coils of pipe, and set in tanks of running water.

The vapors are condensed to a liquid, and products of dif-
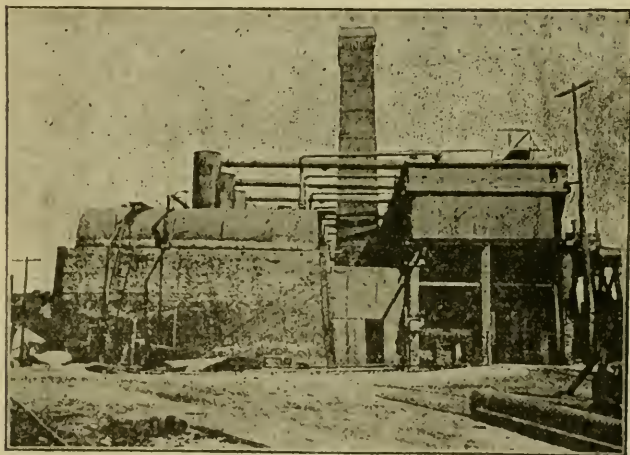
Fig. 2—PETROLEUM STILL.

ferent densities are obtained, the lighter portions coming off first, the different portions being separated according to the indications of the hydrometer. These portions are known as the "naphtha distillate," the "burning oil distillate" and the "lubricating oil distillate." These are treated in tall tanks, called "agitators," with sulphuric acid to remove the "skunks," as the bad smelling portions are called, and then washed with alkali and water.

This is the treatment more particularly for oils that have been prepared by the "cracking process," which consists of breaking down the molecules of the very heavy oils into

smaller and lighter ones, just as a dish is cracked into small fragments. Oils which have been prepared by straight distillation, particularly one in which dry steam is used, to lift the heavy vapors out of the still, are not usually acid treated.

Fig. 3—PETROLEUM CONDENSER.

Both classes of oils may be filtered through bone charcoal or fuller's earth to improve the color. There seems to be a clearly defined impression that the loss of color is also accompanied by a loss in the lubricating value. Acid-treated oils emulsify more readily with water, partly on account of

the "sulpho" compounds which they contain, and are less desirable as lubricants. Sulphonic and sulphuric acids are difficult to remove completely.
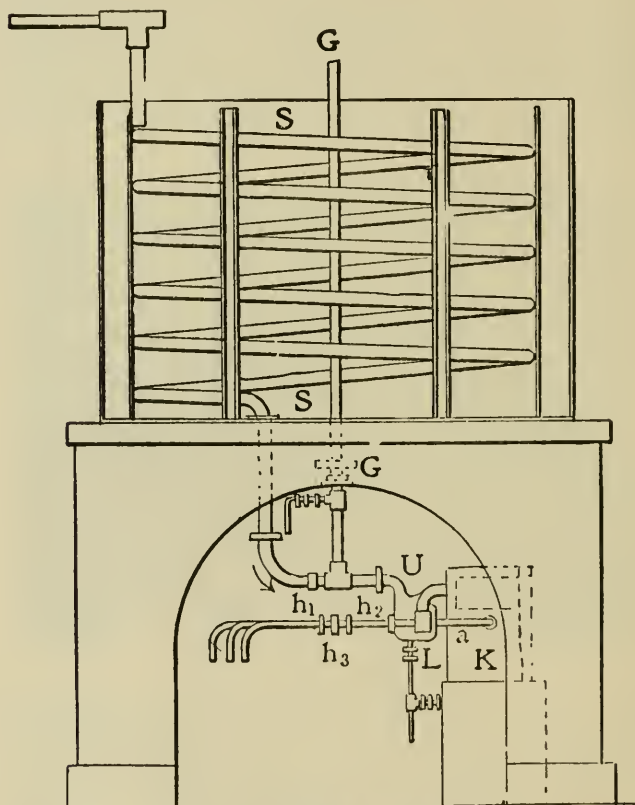
The following table shows some of the principal products derived from petroleum, together with their properties and uses:

Naphthas.

Name	Gravity Be.	Boils, °F.	Use
Cymogene	110-100	32	Ice machines
Rhigolene	100-90	65	Anesthesia
Petroleum ether	90-80	100-150	Gas machines
Gasolene	80-75	150-190 }	Oil extraction
Naphtha	76-70	160-210 }	Motor stoves
Ligroine	67-62	160-225	Motors for
Benzine	62-57	225-300	turpentine

Burning Oils.

		Fire test	
Export oil	57-53	100	Burning(China)
Export oil	53-50	120	" (Eng.)
Kerosene	50-47	135-150	" (Amer.)
Mineral sperm	39-36	300	"

Lubricating Oils.

	Gravity °Be.	Flash °F.	Cold °F.	Viscosity, Sec. at 70 °F.
Spindle Oils:				
No. 4 Eagle	34.4	320	25	72
No. 1 Eagle	30.3	390	25	200
Engine oil	31.7	300	30	49
Engine oil	27.9	350	32	104
Engine oil	24.9	395	32	220
Engine oil	23.1	415	34	400
Cylinder oil	28.1	500	50.55	117*
Cylinder oil	27.5	550	50	150
Cylinder oil	26.1	600	35	200

*at 212° F.

Organic Oils

Oil is found in all parts of animals and vegetables, although more is contained in certain parts than in others. In land animals the fat occurs on the back, abdomen, and upper parts of the legs; in fish, around the body, as the blubber of the whale; in the head with the blackfish and sperm whale; throughout the whole body, as in the menhaden, and in the liver, as with the codfish and shark.

With vegetables, oil is mostly found in the seed, although with the essential or volatile oils, it occurs in the flower, as with the rose; in the bark, as with cinnamon; and in the root, as with sassafras.

These oils are contained in cells composed of animal membranes or of cellulose, and to obtain the oil the cells must be ruptured. This is usually done by heat in the case of animal oils, and with vegetable oils by grinding and pressure. The membranes containing oil soon putrefy on standing, causing the oil to turn rancid and have a bad odor; consequently, animal oils should be rendered as soon as possible.

The animal fat is cut up into small fragments and filled into large digesters or autoclaves, Fig. 4, heated with direct steam. The apparatus is filled and discharged by manholes at the top and bottom. When steam at 50 pounds pressure is admitted, the cell walls are broken down and the melted fat flows with the water to the bottom of the apparatus. The gases evolved, together with some steam which is condensed, pass to a chimney or sewer. After a few hours' heating the steam is shut off, the pressure released, and the autoclave allowed to stand in order to separate the oil from the water.

The separation can be determined by means of cocks at various heights upon the autoclave. When this has taken place, the water is drawn off as completely as possible through these cocks, and the oil through another. The animal tissue (cell walls or membranes), "scraps" or "cracklings" are discharged through the bottom manhole. These cocks serve also as exits for the water used in washing the fat after it is packed in the autoclave.

With the vegetable oils the seeds, hulled in some cases, are crushed by rollers or edge-runners, rupturing the oil-cells, the resulting mass being steamed or "cooked" to com-

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plete the rupture and render the oil more fluid, and then pressed in duck or horse-hair bags in a hydraulic press. This press consists of a framework supporting the top, against which the bags are pressed by the ram, which is forced out of its cylinder by pressure of water or oil.

Oil obtained by cold and moderate pressing is the best. The yield is small and after pressing in this manner, the press is enclosed and heated by steam, and the pressure increased with a corresponding increase in yield. Wedge, screw, knuckle-joint, lever and eccentric presses are also used.
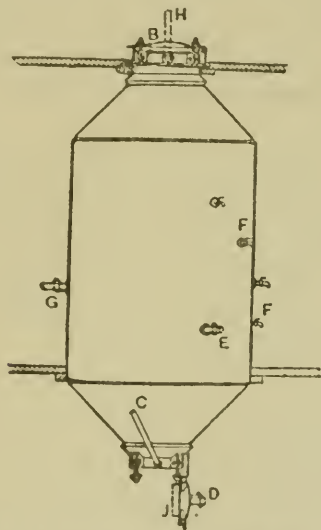
Fig. 4—A DIGESTER FOR ANIMAL FAT.

Vegetable oils can be prepared by dissolving them out from the crushed mass with naphtha, carbon bisulphide or tetrachloride. To this end the crushed seeds are filled into boiler-iron extractors like the autoclave, which are provided with false bottoms, and the solvent, as naphtha, caused to circulate through the mass, dissolving the oil. The solution is then heated, and the solvent distilled off, leaving the oil. The condensed solvent can be used again.

A larger yield of oil is obtained by this method, but it con-

tains more impurities, such as gums, gelatinous matters, etc., for the naphtha dissolves these as well as the oil. Furthermore, the odor of the solvent is difficult to remove completely from the oil. The residue left in the extractors, containing less oil, is not as valuable for cattle feed as the press cake, and can be used only as a fertilizer or fuel. The plant required for this process is more complicated and expensive and more dangerous as a fire risk.

The oils when freshly expressed or rendered are often dark in color or contain resinous, gummy, or gelatinous matter, fatty acids and water and require to be refined or clarified. The treatment varies with the oil. With cotton seed, whale, and sperm oils they are treated with caustic soda lye, which combines with the color and saponifies the fatty acids, the soap thus formed carrying down the gummy matters as "foots."

Some of the animal oils, as lard, are in addition treated with compressed air and fuller's earth to improve the color. Certain other oils are bleached with acids and bichromate of potassium or sodium peroxide. Frequently, as with linseed oil, water and mucilage are removed by allowing the oil to settle for twelve to eighteen months, becoming an "aged" or "varnish oil." Besides this artificial means, oils are bleached by exposure to sunlight in shallow tanks.

Castor Oil is semi-drying oil obtained by pressing castor beans, which contain about 50 per cent. of oil. It is a colorless or pale-greenish, heavy, thick, and viscous oil. It is adulterated with blown oil (for few others are heavy enough to serve as adulterants), such as linseed, rape or cottonseed and rosin oils. These, though 10 per cent. be present, cause a turbidity with alcohol with which castor oil is miscible in every proportion. Castor oil is employed in medicine, in the manufacture of Turkey-red (sulphonated) oil, for soap making, illumination, as a belt dressing, and on steamships as a lubricant.

Cocoanut Oil or fat is obtained from the fat of the coaconut, the fruit of a species of palm. The finest quality is that prepared in Malabar from the fresh fruit. Inferior varieties are made from the dry kernels or "copra," which contain from 60 to 70 per cent. of oil. It is a solid, white fat of bland taste and peculiar odor, readily turning rancid. It is soluble in two

volumes of absolute alcohol at 90° F. It is used in soap-making, particularly for salt-water soaps, in candle-making, and as a table fat, the various "nut" margarines.

Corn or Maize Oil is a semi-drying oil obtained by pressing the germ of the corn separated in the manufacture of starch or alcohol. It is a pale-yellow to golden-yellow oil, excelling cottonseed oil in absorbing oxygen from the air. It is adulterated with mineral and rosin oils, shown by lowering the Maumené value, and in the case of mineral oil by the lower specific gravity. It is used as an adulterant for linseed and lard oils, for painting, burning, lubricating and soap-making, and after treatment with sulphur chloride, as a waterproof and belt dressing and a substitute for rubber.

Cottonseed Oil is a semi-drying oil prepared by pressing the seeds of the cotton plant, which contain about 25 per cent. of oil. When first pressed, the oil is ruby-red or black, and is purified by treatment with caustic soda, carrying down the color and gelatinous substances as "cottonseed foots." The oil thus obtained varies in color from white to deep yellow. It belongs to the class of the semi-drying oils, slowly absorbing oxygen from the air and "gumming," which renders it less valuable as a lubricant. Cottonseed oil is rarely adulterated. It serves, however, to adulterate other oils, where its presence can be shown by the Halphen test, already described. Other uses are as a screw-cutting oil, for soap-making, and as a salad and hardened cooking oil.

Elaine or Red Oil. Commercial oleic acid. Oleine. The name "oleine" is applied by the oil trade to a limpid oil, really oleic acid, obtained by the breaking down of a fat, by saponification with a mineral acid or by distillation. Similarly the companion term "stearine" (usually wrongly pronounced sterreen), really stearic acid, is the solid part obtained.

Elaine oil is made by heating fat in closed vessels or autoclaves, similar to that shown in Fig. 4, with 2 to 4 per cent. of lime or sulphuric acid. This probably begins the saponification, as the process is called, which is completed by the steam. It is like the action which takes place in making soap (Ol-oleic acid):

$$C_3H_5OI_3 + 3\ H_2O = C_3H_5\,(OH)_3 + 3\ HO1$$
oil + water = glycerine + oleine

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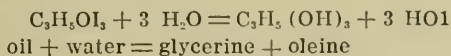
Because these oils are acid they are readily and completely saponifiable, hence they are much used as wool oils, and may be adulterated with any of the cheaper oils, as cottonseed or mineral. In their use it should be borne in mind that they are really acids, not oils, and consequently will corrode metals. This is seen sometimes in their corrosive action upon the pins of the combs in wool combing, the leather backs of the card clothing, and particularly upon articles of brass or copper.

There has been a more or less justly founded prejudice against the use of elaine oils on account of their liability to produce spontaneous combustion. The writer well remembers some white woolen yarn which had been stored some months "in the grease," on spindles tightly packed in wooden cases in a cool basement. When opened the yarn was rotted and charred, and had it not been for the fact that the cases were tightly closed, preventing a rapid oxidation, fire would undoubtedly have resulted from the spontaneous oxidation of the oil. Recent work of Swett and Hughes seems to indicate that a small percentage of iron in the oil will bring about this result.

Horse Oil is a non-drying oil prepared by rendering dead horses. It varies in consistency from an oil to a grease, and in color from light to deep yellow. It is used for mixing with and adulterating other oils.

Lard Oil is a non-drying oil obtained by pressing lard. The lard is chilled, brought into press-cloths and pressed in screw or chain presses at a pressure of about four tons to the square inch, yielding from 40 to 60 per cent. of oil. The oil is valued according to color, which varies from reddish brown to very light straw yellow, according to the lard from which it is pressed. Frequently the color is improved by refining with fuller's earth. The grades in the market are Prime, Pure, Extra No. 1, Crackling Oil, No. 1 and No. 2, Prime being the best. The odor varies from almost none to offensive in the No. 2 samples.

Lard oil is adulterated with cottonseed, corn, and neutral petroleum oils. Cottonseed is shown by the Halphen test and by the higher Maumené (sulphuric acid) test. Should the oil not give the Halphen test, but show a high Maumené value, it is an indication of the presence of corn oil. Neutral petroleum would be shown by the flash test and a low Mau-

mené value; ordinary petroleum, by the "bloom" or fluorescence. The oil is used as a screw-cutting oil, for burning (signal oil, miner's lamp oil), for oiling wool preparatory to spinning, and in soap-making.

Linseed Oil is a drying oil prepared from flaxseed, which contains about 40 per cent. of oil. The oil is called Calcutta and Western oil from the locality where the seed is grown. It is of a golden yellow color and pleasant odor. When exposed to the air it absorbs oxygen, forming a thin film of a gummy insoluble substance, hence its use as a paint oil. This film oil is, however, quite porous, and of little protection unless it carries a pigment in it.

Linseed oil is an example of a drying oil, and it may dry so rapidly as to produce heat and cause fire by spontaneous combustion. *Great care should consequently be used to burn up all rags or waste saturated with animal or vegetable oils, particularly linseed, not even saving them for use on the following day.* This caution does not apply to mineral oils or mixtures of the above oils with mineral oils where the latter constitute half the volume of the mixture. The oils which are liable to cause spontaneous combusion are: first, the drying oils, as linseed and menhaden; second, the semi-drying oils, as corn, cottonseed, and rapeseed, also neatsfoot, lard, and "red oil."

Linseed oil is adulterated with corn, cottonseed, menhaden, and rosin oils, all of which retard the drying tendency.

Neatsfoot Oil is a non-drying oil obtained, as its name signifies, from the feet of neat cattle, that is, steers, cows, etc. The hoofs are separated, the bones of the feet disjointed and the latter boiled with water. The emulsion is allowed to settle and the oil which rises is separated. As is the case with all oils, that which is obtained with the least degree of heat or pressure is the best. It is of light yellow color, a bland taste and peculiar odor, with little tendency to turn rancid. It is adulterated with fish, rapeseed, cottonseed, and mineral oils; the first three would raise the Maumené figure; the last lower it. It is also adulterated with other hoof oils, as sheep-trotter and horsefoot oil, which are difficult of detection. It is used as a lubricant by itself or compounded, as for currying leather.

Olive Oil is a non-drying oil prepared by pressing or extracting the fruit of the olive tree. The oil varies greatly

according to the tree, there being no less than 300 varieties in Italy alone, and also the degree of ripeness and manner of gathering the fruit itself. It varies in color from almost colorless to golden yellow or green. As used for oiling wool, it may contain a large amount, from 1 to 24 per cent., of free fatty (oleic) acid. This, while possessing the advantage of being readily scoured out of the finished goods, has a serious disadvantage in that it corrodes the pins of the wool combs, and has a tendency to rot the leather backs of the card clothing. The free fatty acid (more than 5 per cent.) renders it unfit as a lubricant and as a burning oil, as it attacks the metals, and also causes charring of the wick. It is often adulterated, cottonseed, peanut, rape, sesamé, poppy seed, and lard oils being used for the purpose.

In view of the fact that a high grade textile oil is sometimes used as an edible oil, it is at present denatured with the oil of Rosemary. Cottonseed oil would be shown by the Halphen test, and the high Maumené figure (76), peanut oil would also be shown by the high Maumené figure. The service of a skilled chemist would be required to determine the presence of these adulterants, with the exception of cottonseed, and in some cases even he could not be sure. Olive oil is used as a table oil, for oiling wool, as a soap stock and as a burning oil.

Palm Oil or Fat is prepared from the flesh of the palm nut, which grows in immense quantities on the west coast of Africa. The fruit is fermented, whereby the oil rises to the top; or it is expressed from the fresh fruit. Owing to the method of preparation its properties are quite varied. It is of a buttery or tallowy consistency, of orange yellow to dirty red in color, due to carotin, and it has an odor in some samples recalling that of violets. It can be bleached by heating to a high temperature, treatment with acid or sunning. Palm oil is used like cocoanut oil for soap and candles and for coloring other oils.

Palm Kernel Oil is obtained from the seeds or kernels of the fruit from which palm oil is made. It resembles cocoanut oil very closely, and, like it, is chiefly used in soap making.

Rapeseed Oil is a semi-drying oil obtained from seeds of plants belonging to the mustard family, turnips and their varieties. The oil is pale yellow to yellow, of a peculiar odor and harsh or pungent taste. It is adulterated with cottonseed

and refined fish oil. The former would be detected by the Halphen test; the latter, by the odor. It is used as a lubricant, more particularly in Europe, and as a burning oil.

Rosin Oil is obtained by the distillation of common rosin in stills holding about thirty barrels. About 85 per cent. of oil is obtained. This is distilled, redistilled and sometimes distilled again, giving "rosin oil first run," "second run," "third run," and "fourth run." A small quantity of rosin spirits is obtained at the same time. "First run" is employed in making axle-grease, in oiling leather and making cements; "second run" is used in printing ink, and in currying; and the "third" and "fourth runs" are used to adulterate other oils. Rosin oils are thick, reddish-brown, viscous liquids of high specific gravity, 0.981-0.987, and peculiar odor.

Sesamé or Teel Oil is a semi-drying oil made from the seeds of the sesamé plant. It is, according to the degree of refinement, of a pale to deep yellow color and pleasant taste. It is adulterated with cottonseed, peanut and rape oils and used as an edible and burning oil and in soap making.

Soy or Soya, Chinese bean oil, is a drying oil, and, as its name denotes, obtained from the Soy bean, formerly grown chiefly in China and Japan, but now also in this country. It is pale yellow to brown in color. It is employed in soap making, for boiled and blown oils and grinding with colors. It dries slowly and is tacky, and can to a certain extent replace either cottonseed or linseed oil.

Sperm Oil. Real sperm oil, a non-drying oil, is obtained from the huge cavity in the head of sperm whales. The term is also applied to the oil obtained by trying out the blubber, as well as to the oil from the Arctic sperm or bottlenose whale. The crude oil, as unloaded from the ships, is packed in ice, thus chilling it, is shoveled into bags and pressed after the manner of lard. The solid part after refining forms spermaceti; and the liquid portion, sperm oil. It is a limpid oil, of a pale yellow color and faint odor, and one of the best lubricants we have. Of the fatty oils it has the lowest viscosity and it varies less than that of any other oil with increase of temperature. The common adulterants are whale, mineral and rapeseed oils, also liver oils. Whale oil is indicated by the strong fishy odor and nutty taste; mineral oils, by the low flash test corresponding to a gravity of 0.880; and rapeseed oil, by the peculiar odor and taste. It is

used as a lubricating and formerly as a burning oil.

Tallow or Ox Oil is a non-drying oil obtained from beef tallow after the manner of the manufacture of lard oil from lard. It is a light yellow, bland oil, resembling tallow in odor and is employed in mixing with mineral oils as cylinder oil.

Turpentine is made by the distillation of pine resin or pitch in copper stills of about 800 gallons capacity. To aid the process, a stream of water is run into the still, making a distillation with steam. The residue in the still is run off into barrels, forming the rosin of commerce. The yield and quality vary according to the length of time the trees have been producing resin, both growing inferior with age. The resin of the first season is called "virgin dip," and produces the finest quality of rosin, "W. W." (water white) or "W. G." (window glass). Other grades are "V," "U," "T," etc., to "A," which is the poorest and blackest.

Turpentine is a colorless liquid of peculiar taste and odor. On exposure to the air it evaporates and becomes partially resinous. It is adulterated with petroleum products, benzine and kerosene, which would be shown by the low flash test and gravity, and by the bloom in the case of kerosene. Wood turpentine, obtained from the distillation of pine stumps and wood with steam, is in many ways a satisfactory substitute for the resin turpentine.

Whale Oil is a non-drying oil prepared from the blubber of whales after the manner of sperm oil, to which it is similar. It has a strong fishy odor, a nutty taste, and is light yellow to brown in color. A customary adulterant is seal oil, which it is practically impossible to detect. It is used as a leather dressing, as a burning oil, and for lubricating purposes.

Blown Oils. Blown, base, thickened or oxidized oil is usually prepared by heating the oil from 160 to 230° F. in a jacketed kettle and forcing a current of air through it. After the action is once started, no further heating is usually necessary. The color of the oil darkens somewhat, but the specific gravity and viscosity are much increased.

The oils submitted to this process are chiefly rape and cottonseed, although it is often applied to linseed, sperm, and seal oils. The blown oils are used to mix with other oils to increase their viscosity for lubricating purposes.

Wool Fat. This is found in commerce in the form of British or American degras, suint, lanoline, wool grease recovered or Yorkshire grease. As the names denote, this is the greasy material obtained in the washing of wool. Wool contains from 20 to 80 per cent. of impurities, made up of (*a*) wool grease, the fatty matter secreted by the skin of the sheep, amounting to 6 to 17 per cent. of the wool; (*b*) suint, also a skin secretion but soluble in water, consisting of the potassium salts of oleic, valeric and acetic acids, with sulphates, phosphates, chlorides and nitrogenous compounds amounting to 5 to 24 per cent. of the wool; and (*c*) dirt, earthy matter and manure.

These substances are removed from the fiber in two ways, by scouring with soap and alkali, and by extraction of the grease with solvents, usually naphtha or carbon tetrachloride and subsequent washing. These foul and ill-smelling wash-waters are usually run into the streams and form one of the most troublesome sources of pollution. Wool grease is saponified with difficulty, but readily emulsifiable and is deposited along the entire length of the stream.

To recover the grease, the wash-waters are allowed to stand to settle out the sand and dirt, then "soured" with sulphuric acid, whereupon part of the grease floats and part settles. These portions are collected and pressed hot through canvas. The grease thus obtained contains, besides wool grease, the fatty acids of the soaps used and also traces of sulphuric acid. Or the solvent is distilled off from the solution of the grease and the latter strained into barrels. The product thus obtained is of lighter color and better quality than that obtained by the acid process, is free from sulphuric acid and practically so from fatty acids and is the only one to which the term wool grease is properly applied.

Properties. It is a light or dark brown substance of a peculiar, unpleasant odor and salvy consistence. It is not wholly saponified by alcoholic potash, requiring sodium alcoholate to complete the process. It mixes with water readily and forms emulsions which are unusually permanent, particularly if any alkali is present, and which may contain as much as 80 per cent. of water. It is not readily oxidized on exposure to the air.

Compositions. It is a complex mixture of alcohols and es-

ters, a collection of waxes and not a fat; the esters are largely those of cholesterol and its isomers. Lanoceric, lanopalmic, myristic, carnaubic and other oily and volatile acids, ceryl and carnaubyl, alcohol, cholesterol and isocholesterol are some of the compounds which have been found in the grease.

Constants. From what has been said, it will be seen that it is impossible to give any figures to which the name constant can be properly applied.

Adulterants. Wool fat is rarely adulterated, the usual one being mineral oil, not intentionally added, but coming from the wash waters. It is detected by its resistance to saponification and insolubility in acetic anhydride, which converts the cholesterol into the acetate. Rosin oil may also be used and is detected by partial saponification with potash, the object being to saponify the rosin acids in the oil and not the cholesterol esters, and the liberation of the rosin acids, which are submitted to the Liebermann-Storch test.

Uses. Degras is used to mix with oils for currying purposes, with lard and similar oils for "wool oils," and when purified forms the lanoline of the Pharmacopoeia. This, from the ease with which it is absorbed by the skin, makes an admirable basis for salves and ointments. There are two varieties, one anhydrous (*adeps lanae*), and one, lanoline proper, with about 25 per cent. of water. It is used to replace tallow in certain cylinder oils.

Distilled Grease, Oleines and Dressing Oils. This is prepared by distilling wool grease in cast-iron stills, using superheated steam to carry forward the heavy vapors. A stearine and oleine are obtained by cooling and pressing the distillate. Wool fat pitch is left in the retort.

Properties. The crude stearines are brownish and, like all these products, of a peculiar penetrating aldehydic odor. When refined they are white and crystalline. The oleines are light yellow to dark brown and have a greenish fluorescence, which must not be mistaken for the bluish "bloom" of the mineral oils used as adulterants.

Composition. The esters originally present in the wool fat are broken down into hydrocarbons and fatty acids of high molecular weight, stearic, palmitic, and oleic, which in turn are dissociated into acids of lower molecular weight and

other hydrocarbons. The following equation, cited by Smith, gives an idea of what may have taken place:

$$C_{17}H_{31}COOC_{16}H_{33} = C_{15}H_{31}COOH + C_{16}H_{32}$$
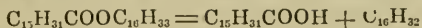
Cetyl palmitate = Palmitic acid + Cetene.

These hydrocarbons have been investigated by Gill and Forrest. They were found to be olefines, from hepta decylene, $C_{17}H_{34}$ Bpt. at 1 mm. 95°-100°, an oil, to triacontylene $C_{20}H_{60}$, Bpt. 186°-193°, a wax-like solid. They can be distinguished from hydrocarbons intentionally added, by the determination of the bromine addition and substitution numbers, the optical rotation, and index of refraction. These constants, obtained on hydrocarbons separated from some distilled grease oleines by Gill and Mason, are shown in the table below.

Oleine	Sp. Gr.	Bromine Add.	Subs.	Optical Rotation	Refractive at 20° C.
A	0.896	28.8	14.2	+17° 58′	1.4967
B	0.902	25.1	14.8	17° 36′	1.4991
C	0.896	21.5	16.8	15° 13′	1.4948
	0.848	4.4	5.6		1.4662
Mineral Oils	to	to	to	1° 25′	to
	0.863	5.9	8.4		1.4760

The examination of distilled wool grease is conducted upon the same general lines as indicated in the case of wool fat. Lewkowitsch obtained the following results:

Free fatty acids (oleic)	37%	47%	52%	37%
Glycerides	33%	3%	18%	18%
Unsaponifiable Matter	30%	51%	30%	45%
Flash point, °F.	364°	360°	370°	346°

Adulterants. The only adulterant is mineral oil, the detection of which has already been given.

Uses. Distilled grease stearine is used in soap and candle making; the oleine is used as a wool oil.

Oil Foots. The term "foots" is applied by the oil and paint trade to any sediment obtained in the manufacturing or storing process. It is a mixture of oil, the impurities contained in the oil coming from the seed, or "mucilage," as it is called, coloring matter, water, dirt, and where alkali has been used in the refining process of the saponified oil or soap.

Properties. Cotton-seed oil foots or soap-stock varies in color from light, dirty yellow, through dark green to deep red, changing to black on exposure to the air. The odor is that of decomposed fish, due probably to methyl amine. If

It contains more than 40 per cent. of water it ferments easily in hot weather, and the soap made therefrom is poorer in color than that made from fresh stock.

Composition and Analysis. This has been given under *preparation;* it varies with the amount and strength of the alkalies used. The total fatty acids vary from 35 to 65 per cent., 45 being a fair average; less than 40 per cent. cannot be delivered on contracts. The specific gravity is from 0.97 to 1.04, 1.00 being the average.

A typical analysis is as follows:

Water	36.0
Fatty anhydrides	48.5
Glycerine	4.0
Caustic soda, Na_2O	5.8

Uses. It is used for the manufacture of soap, textile or mill soaps particularly, and is by far the cheapest soap-making material on the market. Many of the "washing powders" are composed of settled foots soap and soda ash. In England the foots are distilled with superheated steam, after the manner of wool grease, which has already been described. On oleine, stearine and cotton seed stearine pitch are the products. Other foots beside cotton seed are linseed, whale, sperm and olive oil.

Fuller's Grease. This product, known as "seek oil" (England) and recovered oil, is obtained from the water in which woolen cloth has been washed, by a process similar to that by which wool fat is produced. It consists of the oil which has been used in carding and spinning the wool, together with the fatty acids obtained from the scouring soap used, and those which existed in the oils as such. Olive, lard, neat's-foot, saponified, and distilled red, or "elaine oils," "distilled grease" oleines and mineral oils, sometimes mixed with wool fat or degras, or some of the oils used for this purpose.

Composition. This will vary according to the oils and soaps used, and the results obtained should be compared with the constants of the oils originally employed. If the oil is to be used again as a wool oil, the spontaneous combustion and saponification tests should be applied.

Black Oil. This is the term applied to oil extracted from the greasy waste of woolen mills and, except for mineral oil

coming from the machinery, is the same as that upon the wool itself. It should not be confounded with a petroleum product, black oil, a crude petroleum from which naphtha and burning oil have been distilled and used for freight-car lubrication.

Garbage Grease. This is a grease obtained by the extraction of garbage with naphtha or carbon tetrachloride. It is used for the manufacture of cheap toilet soap, or distilled as is wool fat.

Lubricating Greases.

Gillett divides the greases into six classes:

1. The tallow type, a mixture of tallow with palm oil soap with some mineral oil; this was common thirty years ago.

2. The soap thickened mineral oil type, a mixture of mineral oil usually with lime or sometimes soda soaps, the commonest type at present.

3. Types 1 or 2 mixed with graphite, talc, or mica.

4. The rosin oil type: a mixture of rosin oil thickened with lime, or sometimes litharge, with mineral oil. They contain often 20 to 30 per cent. of water and are used as gear greases. They may contain also tar, pitch, ground wood, or cork, and any of the fillers mentioned in 3.

5. Slow-flowing oils: Oils or thin greases stiffened with "oil pulp" or "dope," i. e., aluminum oleate.

6. Special greases with special fillers.

These greases show a high coefficient of friction at first, causing a rise of temperature which melts the grease—producing the effect of an oil-lubricated bearing. The graphite greases showed an unexpectedly low lubricating power; the rosin greases showed a high friction at first, but, after the bearing had warmed up, compare well with the more expensive greases. The high moisture content would seem to have the advantage of making them less sticky. The lime-soap greases (Class 2) are not as good as the tallow greases (Class 1), and are inferior as lubricants to those mixed with soda soaps.

By choosing the materials, soft or hard soaps, and light, medium or heavy oils, or solid greases, with suitable fillers—talc or graphite—and varying their proportions, greases can be made in any desired consistency, from the semi-fluid oil to the hot neck grease.

Greases are in many cases to be preferred to oils, particularly where oil spots from the bearings are to be avoided; the most fluid grease that will stay in place and do the work should be chosen as with oils. They are used upon dynamos, shafting, gears, and where heavy pressure is applied, as in the trains of rolls in rolling mills. Some of these greases have received special names, as Fiber Grease, Gear or Pinion Grease, Graphite Grease, Petroleum Grease and Hot Neck Grease.

The following table shows the composition of some of the greases:

COMPOSITION OF SOME GREASES.

Name	Flash pt. °C.	Mlt. pt. °C.	Consistence 20° C.	Water	Ca. Soap	Filler	Min. Oil	Fatty Oil	Free Acid	Coeff. Friction
Graphite	195	93	18	tr.	11	16	56	17	0	.097
Summer motor	160	87	170	tr.	38	..	36.5	25	tr.	.075
Winter motor	175	86	7	tr.	23	..	40	37^5	6.1	.063
K$_1$	193	85	24	0.2	16	..	67	16	0	.057
K$_2$.................	195	93	66	0.3	20	..	60	20	0.3	.054
Auto	190	79	11	1.0	19	..	60	20	tr.	.046
Tallow	210	52	150†	2.5	..	{ 1.4^1 2.1^1	22	73.5	0	.022
Tallow xx	215	49	200	tr.	..	30^7	20	48	0	.029
Lead resin oil	240	102	7	24.7	..	1.7^2	..	0	0	.067
Lime resin oil	198	77	31	tr.	..	9.9^3	..	0	0	.048
Lime resin oil	198	75	4	20.0	..	7.8^3	..	0	..	.036
Soda grease	215	83	35	0	..	22^4	78^5	0	0	.019
Slow-flowing	210	76	27	0	9.8	12.9^4	70.3	7	0	.026
No. 4 Petrolatum ..	247	47	6	0	..	..	100	--0	0	.018
Lard Oil	265	5	0	0	..	..	0	100	..	.011

†Estimated. ^{1}Potash ^{2}Lead soap. ^{3}CaO. ^{4}Soda soap. ^{5}Mainly palm oil. ^{6}Oil of 24.2° Be. ^{7}Paraffin.

Fiber Grease is so called because it appears to be fibrous, especially when pulled apart; it is an anhydrous soda or potash soap (Class 1) mixed with mineral oil. **Gear Grease** is usually a mixture of fiber grease with mineral oil, or it may contain rosin oil (Class 4). **Pinion Grease** is commonly made from petroleum residuum (still bottoms); pine tar is often added, and in some cases the grease consists solely of this tar, to the detriment of its lubricating qualities. **Graphite Grease** is a mixture of about one part graphite and two parts

gear grease; it is especially useful in wet places, as it is not easily washed out of the bearings, particularly if it be compounded with a lime soap. **Petroleum Grease** is a heavy vaseline-like body obtained from still residues after the cylinder oil has been distilled off. **Hot Neck Grease** is the stiffest of all the greases; it is usually a stearine or wool grease pitch, or petroleum residuum mixed with rosin talc and graphite. The tests applied to greases are much the same as those applied to the oils modified as the differences in composition and between the solid and liquid state require.

The following tests are usually applied to the greases: flash, free acid, dropping point, soap content, free oil or fat, saponifiable and mineral; free lime, fillers and water.

Grease or "Cup Grease" should be homogeneous, and contain at least 80 per cent. mineral oil of 24°-28° Bé.; it should be neutral—containing neither free alkali nor fatty acids, nor should it contain grit nor useless filler, as paraffin wax. The ash should not exceed 2.75 per cent. and the loss or evaporation for an hour at 110° should not exceed 3 per cent.

Miscellaneous Oils.

Automobile or Gas Engine Oils. Gas engine oils, particularly for the cylinders, should possess as their chief requisite, besides that of lubrication, the property of not carbonizing at the temperatures attained. The liability of carbonization seems to be intimately connected with the amount of tarry matter yielded in the gumming test and residue in the carbon residue test. For automobiles, oils of the following characteristics have yielded good results: Flash 400°-470° F., viscosity 180-185 at 100° F., gumming tests very slight or slight. For large size gas engines, probably a heavier oil would be required, having these characteristics. Gravity 26-28° Bé., flash 400-475° F., viscosity 250 seconds at 100° F.

Belt Oils or Dressing. Where the object is the softening of the belt these oils are usually mixtures of solid fat, waxes, degras or acidless tallow (70 per cent.) with castor or fish oils (30 per cent.) to make the belts cling; in some cases they are mixtures either of corn or cotton-seed oils which have been treated with sulphur chloride, with mineral oil and thinned with naphtha, or they may be mixtures of the above fats with rosin oil. These latter are less desirable. Preparations containing wood tar are also used.

Crank Case Oils. These should emulsify but little with water, consequently should be pure filtered mineral oils and not acid treated. Much seems to depend upon the water with which the oil is mixed in the crank case, so it is difficult to predict how oils of practically the same constants will behave with different waters. An oil giving these figures has proved eminently satisfactory, gravity 26°-27° Bé., flash 455° F., viscosity 100 at 212° F.

Cylinder Oils. These are divided into low and high pressure. The problem to be met consists in making the oil adhere to the surfaces of the piston and valves. This is accomplished by the addition of some fatty oil which adheres to the metal and the mineral oil adheres to it. The action of the fatty oils would seem to be analogous to that of a mordant in fixing dyes. Pure fatty oils while they have been, and may now in some cases (with low pressures) be used, are open to the objection that these, being glycerides, are decomposed by high pressure steam with the liberation of fatty acids which attack the iron of the cylinder, causing pitting and scoring.

On the other hand, when the condensed water from the exhaust steam is used as boiler-feed water, the fact that these fatty oils emulsify so well with it, renders it necessary to use pure mineral oils. The cylinder stocks, that is, the pure petroleum bases, have the following characteristics: Gravity 23-28° Bé., flash 500-630° F., viscosity 100-230 at 212° F. For superheated steam, the following figures are given for the oil to be used: flash point 625-640° F., viscosity 315-325 at 212° F. The fatty oils used have already been mentioned and vary in quantity from 1 to 25 per cent.; the wetter the steam, the larger the amount of compounding.

Dressing or Finishing Oils are usually either distilled grease oleines or soluble oils which are applied to the woven goods to produce a softer finish.

Engine Oils. Engine oils are classed as light and heavy. A heavy oil has a viscosity of 280-340 seconds at 100° F.; medium 175-200 and lights 50-150 seconds at 100° F. Besides being used for engines they find general employment about the mill or works. Where the duty is heavy or the bearings are rough, they are sometimes mixed with animal oils, as lard or whale.

For Diesel engines special oils are required as follows: for high speed marine engines, a neutral, filtered oil of 150 seconds' viscosity at 100° F.; for heavier engines, a filtered cylinder stock of 150 viscosity at 212° F.; for heavy and slow speed engines, an oil of 450 viscosity at 100° F.

Milling Machine or Soluble Oils. These are usually lard, sulphonated fatty or mineral oils, or mineral oils held in suspension by soaps or alkalies, as borax, sodium, carbonate; the soaps are either ammonium, sodium or potassium, with oleic, resin or sulpho-fatty acids. They should not appreciably attack the metals and should form a persistent emulsion. The U. S. Navy requirements are that upon 24 hours' standing upon polished brass or copper, it must not be turned green; German requirements are that a steel plate 30 x 30 x 3 mm. should not lose more than 18 mg. in a 1 or 2 per cent. solution of the oil after lying for three weeks in it.

Neutral Oil. An oil without "cast" or "bloom," obtained by sunning in shallow tanks. The term was formerly applied to oils of 32°-36° Bé., 290°-318° F., flash, and 47-81 seconds' viscosity at 70° F. At present the term includes "viscous neutrals," of a viscosity above 135 seconds at 100° F. and "non-viscous neutrals" below this figure.

Oilless Bearings. These are wooden blocks often of maple thoroughly impregnated with 35 to 40 per cent. of grease which replace metal journals; the grease may be a mixture of paraffin, myrtle or beeswax with stearine, tallow or petroleum jelly.

Screw Cutting Oils. These are often mixtures of 26°-29° Bé., paraffin and 25 to 30 per cent. fatty oil, preferably cotton-seed, although lard and whale are sometimes used.

(a) **Loom Oil.** This is merely a heavy spindle oil: one which the author tested had a gravity of 28°, flash 360° F., and viscosity of 203 seconds. Here, as in the case of the spindle oils, the evaporation test should be low, as the hydrocarbon vapors formed have occasioned serious fires.

(b) **Spindle Oil.** This is the lighter and most fluid of the lubricating oils: the gravity varies from 27-35° Bé., the flash from 320° to 430° F., the viscosity 30-400 seconds at 70° F., and the evaporation test should not be over 4 per cent. Nowhere is the necessity for low viscosity greater than in the case of these spindle oils when the bearings are multiplied by thousands. A case is on record where the increase in the viscosity of the spindle oil stopped the engine and shut down the mill. Besides being used for spindles, it is used for sewing machines, typewriters, etc. For bath spindles, the viscosity may be 95 to 100 seconds at 100° F.; for open spindles, this may be increased to 140 or 150 seconds.

(c) **Stainless oils** are spindle or loom oils mixed with fatty oils, lard or neatsfoot. The fatty oil being more easily emulsified or possibly saponified, aids materially in the scouring process in washing out the mineral oil with which it is mixed. One type of these oils is compounded of 40 per cent. neutral oil, 30 per cent. cotton-seed, 20 per cent. olive and 10 per cent. first pressing castor.

Turbine Oil. Steam turbines require a pure filtered, non-emulsifiable, mineral oil of excellent quality—free from acid and the tendency to resinify, and low in sulphur. As the oil is circulated around the bearings by a pump it should be of low viscosity and gravity, and free from mechanical impurities. An oil of 29-31 Bé., 145-180 seconds' viscosity at 100° F. and 390 to 420° flash has given good results.

Wool Oils. The various oils used in oiling wool have been mentioned under **Organic Oils.** A wool oil should be examined for flash-point, unsaponifiable matter, for fatty acids, the extent to which it will gum on exposure to the air, and liability to occasion spontaneous combustion.

Properties and Tests of Lubricants.

A good lubricant should possess:

(1) Minimum cohesion among its own particles.

(2) Maximum adhesion to the surfaces to be lubricated.

(3) Slight changeability as regards oxidation by the air or by changes in the temperature or pressure of the bearings.

(4) Freedom from acid.

(5) Purity.

A thin film of oil should interpose itself between the bearing metal and the shaft, as the rotation of the latter separates the particles of oil, **low cohesion** makes rotation easier. **High adhesion** prevents the oil from running off the shaft and out of the bearing. **Exposure to the air** may result in rancidity with the animal and vegetable oils, or in resinification with the mineral oils; this is aided by heat and dust. **Heat** produces an evaporation of hydrocarbon gases from petroleum oils, particularly the lighter or spindle oils, increasing the danger from fire.

Inability to withstand cold—high cold test—may result in freezing the oil in the bearings and stopping lubrication. The oil should be sufficiently viscous to prevent it from being squeezed out of the bearing, except by unusual pressures.

Acid attacks and roughens the shaft and bearings. It can be formed by oxidation of the oil or come from the sulphuric acid used in refining.

Purity is freedom (*a*) from water, which may emulsify the oil and diminish its lubricating power (water also gets into the lubricating wicks and diminishes their capillarity); (*b*) from solid matter which would stop up the oilers. This may be metal from the machinery, stearin, dirt, chips, etc., glue from the barrels; coke with mineral oils, cracklings with animal oils, and cellulose or gelatinous matter with vegetable oils.

Rapid Tests.

The Heat Test. Heat about an ounce of the oil in a flask nearly to the flashing point and keep it at this temperature for 15 minutes. A satisfactory oil will darken, but remain clear even after standing a day. A poorly refined oil changes to jet black, and forms a carbon-like precipitate, in consequence of the "sulpho" compound previously mentioned.

Emulsification Test. This shows the extent to which oil will emulsify with water, and should be conducted with a known oil as a means of comparison. The oils are thoroughly shaken together with an equal volume of distilled water and allowed to settle for a day. If "sulpho" compounds are present, they cause the oil to mix with the water, forming a milky suspension with curds in it. A good oil shows a clear, well-defined line between the oil and water with little or no turbidity. The results of this test should coincide with those of the heat test and will usually reveal an "acid-treated" oil, since a filtered oil emulsifies less than a "red" oil.

More Thorough Tests.

The other tests to be made will naturally vary according to the use for which the oil is intended. The viscosity and gumming tests are of cardinal importance, and should be applied to all lubricating oils. If the oil is to be used indoors, the flash, fire and evaporation tests should be applied, as they measure the fire risk. The cold test indicates the availability of the oil at the working temperature. The emulsification test shows the behavior of the oil when in contact with water in the crank case or turbine. The gasoline test shows the heat treatment of the oil or its adulteration with "still bottoms," heavy residues left in the stills. The gravity test indicates the base of an oil, whether paraffin or asphaltic, and the iodine, Maumené (pronounced as if spelled "momenay," with accent on last syllable) and saponification tests serve usually to identify the organic oils.

Gasoline Test. This is performed by dissolving about a teaspoonful of the oil in twenty times as much 86° gasoline from Pennsylvania crude, and noting the amount of precipitate or tar produced. It indicates adulteration with heavy asphaltic oils or tarry still residues.

Viscosity Test. By viscosity we understand the degree of fluidity of an oil or its internal friction, or its "body" or "greasiness," as it is sometimes expressed. Other things being equal, the least viscous oil should be chosen, or, in other words, the most fluid oil that will stay in place and do the work. A case is on record in which the changing of a spindle oil to one slightly more viscous caused the stopping of an engine, and hence the whole mill, due to the increase in friction. Within certain limits, the viscosity may be taken as the measure of the value of an oil as a lubricant, par-

ticularly if the viscosity of the oil under examination is compared with that of other oils which have been found to yield good results in practice.

The instruments employed for the determination of viscosity are constructed upon two different principles: one depending upon the time required for a certain quantity of the oil to flow through a standard orifice; and the other, upon the degree to which a rotating disk is retarded by the viscosity of the oil.
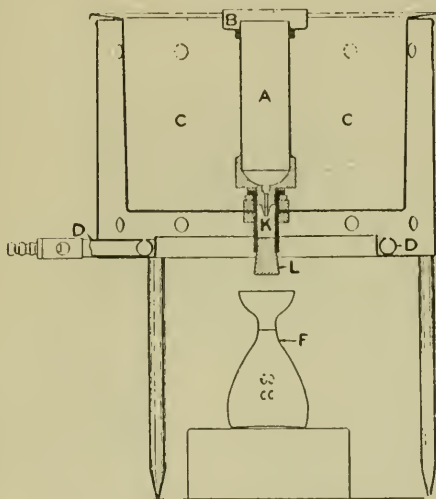

Fig. 5—SAYBOLT VISCOSIMETER.

An apparatus, which may be taken as a type of the orifice instruments, is made in four forms, A, B, and C, and the Universal. Apparatus "A" is the standard for testing at 70° F. Atlantic, red, paraffin, and other distilled oils; "B," for testing at 70° black oils of 0°, 15°, 25°, and 30° cold test, and other reduced oils up to and not including summer cold test oil; and "C" is used for testing at 212° reduced, summer, cylinder, filtered cylinder, XXX valve, 26.5° Be., and other heavy oils. The results are reported in seconds.

The Universal Viscosimeter. This instrument, Figs. 5 and 6, consists of a brass tube A forming the body of the pipette provided with a jet K. The upper part of the pipette is surrounded with a gallery B which enables a workman to fill it

to the same point every time. The pipette is contained in a water bath C, which can be heated either by steam or a ring burner D. A tin cup with spout, a strainer, thermometer, pipette with rubber bulb, stop watch and beaker for waste oil, complete the outfit.

It may be used for testing cylinder, valve, and similar oils with the bath at 212°, and oil at 210°; for testing reduced

Fig. 6—SAYBOLT VISCOSIMETER.

and black oils with bath and oil at 130°; for testing spindle, paraffin, red, and other distilled oils, with bath and oil at 100°. When used for testing at 212°, it may be used with either gas or steam alone or both in combination. If with both, the steam may be introduced slowly; more for its condensation to replace evaporation than for real heating purposes, depending upon the gas flame to reach the boiling point, and keeping it there during the operation of test. The bath vessel should always be kept full during a test, whether at 212°, 130° or 100°. When used at

30

130° or 100°, gas alone is used to bring the bath to the pre-
scribed temperature, and is turned off during the operation
of test, the large size of the bath usually permitting one test
to be made without reheating. The instrument is manipulated
as follows:

1. Have the bath of water prepared at the prescribed tem-
perature.

2. Have the oil strained into one of the tin cups, in which
cup it may be heated up to about the standard temperature.

3. Clean out the tube with some of the oil to be tested
by using the plunger sent with the instrument.

4. Place the cork (as short a distance as possible) into the
lower outlet coupling tube, just enough to make it air-tight,
but not far enough to touch the small outlet jet of the tube
proper (one-eighth to one-quarter of an inch may be enough).

5. Pour the oil from the tin cup (again through the
strainer) into the tube proper until it overflows into the over-
flow cup up to and above the upper edge of tube proper.

6. Again see that the bath is at the prescribed tempera-
ture.

7. Use the thermometer sent with the instrument by stir-
ring to bring the oil just to the standard temperature.

8. Remove the thermometer.

9. Draw from the overflow cup, with a pipette, all the sur-
plus of oil down to and below the upper edge of tube proper.
This insures a positive starting head.

10. Place the 60cc. flask under and directly in line with
the outlet jet and as close to the coupling tube as is practi-
cable to permit of room for drawing the cork.

11. Start the watch and the instant the second hand
crosses the sixty seconds mark twist out the cork with the
right hand.

12. The time required for the delivery of 60cc. indicates
the viscosity.

13. Clean out the tube proper before each test with some
of the oil to be tested.

14. No drill or other instrument should ever be used in the
small outlet jet of tube proper.

The tube should be cleaned out before each test with some
of the oil to be tested, using the plunger P for this purpose.
Black oils or any oil containing sediment should be carefully
strained before testing or "running," as it is technically
termed. The instruments should be carefully guarded from
dust when not in use.

Specific Gravity. By specific gravity we understand the
weight of a substance compared with the weight of an equal
volume of water. The specific gravity of iron is 7.8. This
means that a cubic inch of iron weighs 7.8 times as much as a

cubic inch of water. For accurate work attention has to be paid to the temperature.

In the case of mineral oils, the specific gravity or "gravity" is expressed in terms of the Baumé scale for liquids lighter than water. This is an arbitrary scale, in which water counts as 10°. For example, a 76° naphtha and a 25° lubricating oil, mean that the Baumé hydrometer would sink in the naphtha to the seventy-fifth degree and in the lubricating oil to the twenty-fifth degree, both these liquids being cooled to 60° F.

The mineral oils are usually designated by the Baumé scale,
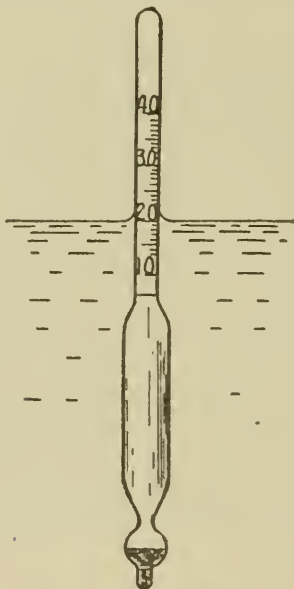
Fig. 7—HYDROMETER.

while the animal and vegetable oils are spoken of in terms of specific gravity. Cotton seed oil, for example, has a gravity of 0.922, meaning that a quart of cottonseed oil is nine hundred and twenty-two thousandths as heavy as a quart of water.

The chief value of the test is to characterize the oil. It is usually made by the hydrometer. A hydrometer jar is four-fifths filled with the oil, a Baumé hydrometer introduced into it, and the depth to which the instrument sinks in the oil read off. This may be effected by placing a strip of white

paper back of the jar and noting the point at which the lower meniscus or curve of the surface of the oil touches the scale, as at 20°, Fig. 7. The temperature of the oil is taken at the same time, and in case it is not 60° F. (15.5° C.), for every increase of 10° F. (5.5° C.), subtract 1° B. from the hydrometer reading. The specific gravity may be found by the following formula, in which B represents the Baumé reading:

$$140 \div (130 + B°)$$

Cold Test. This may be defined as the temperature at which the oil will just flow. The importance of this test is seen wherever oils are exposed to freezing temperatures, as in railroad use on car axles. If the oil is chilled, it ceases to flow and the bearing becomes hot; or, as happened on the East Prussian railroad during the World War, the freezing of the oil in the axle-boxes stops the running of the trains.

The testing apparatus required consists of a 4-ounce vial, a thermometer, a quart can and a freezing mixture.

The four-ounce vial is one-fourth filled with the oil to be examined, a short and rather heavy thermometer inserted in it, and the whole placed in a freezing mixture. When the oil has become solid throughout, the vial is removed, the oil allowed to soften, and thoroughly stirred until it will run from one end of the bottle to the other. The reading of the thermometer is now taken by withdrawing it and wiping off the oil with waste to render the mercury visible.

The chilling-point is the temperature at which flakes or scales begin to form in the liquid, and is determined similarly, by cooling the liquid five degrees at a time.

The freezing mixtures are:

For temperatures above 35° F., cracked ice and water.

Between 35° and 0° F., 2 parts of ice and 1 part of salt. From 0° to 30° below zero, 3 parts of crystallized calcium chloride and two parts of fine ice or snow.

A still more convenient means is the use of solid carbonic acid, "carbonic acid snow," dissolved in ether or alcohol, which readily gives 50° F. below zero.

Flash-Point. By flash-point is understood that temperature at which an oil gives off vapors in sufficient quantity to explode when mixed with air. This point is reached by burning oils in testing when a blue flame passes entirely over the surface of the oil. Like specific gravity, the chief use of the test with lubricating oils is to ascertain if any change

has been made in the oil supplied. With burning oils it determines the safety of the oil. In considering the results of this test, differences of 5 to 7° F. may be disregarded, as duplicate tests upon the same sample may vary as widely as this.

Several forms of apparatus for testing the flash-point of lubricating oils have been devised. Pensky-Martens' closed
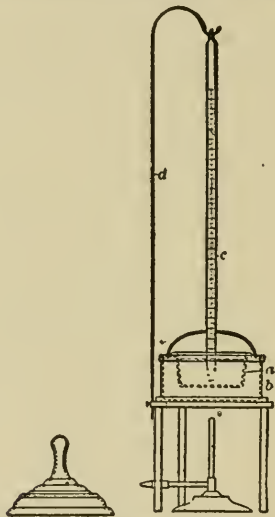
Fig. 8—CLEVELAND CUP.

tester employing a stirrer is used in Germany. Martens states that stirring is unnecessary. Dudley and Pease use an open porcelain dish heated with a Bunsen burner. In this country the "Cleveland cup," Fig. 8, is extensively used. This consists of an open spun brass cup, 1⅜ inches high by 2½ inches in diameter, heated by a Tirrell burner in an air bath. The thermometer is suspended from the wire support directly over the center of the cup so that its bulb is entirely covered with oil, but does not touch the bottom of the cup. The testing flame is a gas jet about ¼ inch in length.

The oil cup is filled with the oil to be tested to within ¼ inch of the top. The burner is adjusted to raise the temperature of the oil 5° per minute. Every thirty seconds, the testing flame is brought almost in contact with the surface of the oil. A distinct blue flame or "flash" over the entire sur-

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face of the oil shows that the flash point has been reached and the reading of the thermometer is then noted. The flash point determined by the "open cup" is higher sometimes by 5° to 10° than that obtained by the "closed cup."

For accurate work the thermometers used should either be graduated by the maker to correct for the stem exposure with half-inch immersion in the bath or corrected for stem-exposure. This is found by the formula,

$$\text{exposure} = d \times 0.00016 \ (t\text{-}t^1);$$

in which $d =$ length of exposed thread in degrees.

$t =$ temperature observed.

$t^1 =$ temperature of the glass of the thermometer itself as shown by a separate thermometer. This correction is additive and, if 200° were out of the bath and $t\text{-}t^1$ equal to 120°, would amount to 3.7°. The thermometers should be frequently compared with a standard.

The free acid contained in an oil lowers its flash point apparently in proportion to the quantity present.

Fire Test. The heating and application of the testing flame are continued as in making the flash test. The temperature is noted at which the oil ignites and burns. The flame is put out by the extinguisher supplied with the apparatus.

Gumming Test. This test indicates the change that may be expected in a mineral oil when in use. The resinified products increase the friction of the revolving or rubbing surfaces. The test is applied by thoroughly mixing and beating together about a teaspoonful of the oil in a cordial glass or small wide-mouthed bottle with 170 grains of nitrosul-phuric acid, and cooling by setting the glass in a basin of water at 50° to 60° F. Brownish spots, or, in case of a bad oil, masses form around the edges and gradually cover the whole surface in the course of two hours. As shown by long experience, the oil showing the least tar is the best oil and also absorbs the least oxygen.

Nitrosulphuric acid is troublesome to prepare, but directions therefor will be found in the writer's "Handbook of Oil Analysis," and it may be replaced by nitric acid and copper. Use ordinary nitric acid, 1.34 sp. gr., drop into this two pieces of No. 15 B. & S. gage copper wire ¾ inch long, and in an hour two more pieces, wetting the wire in water before dropping it into the acid.

Test for Acidity. In a petroleum oil the acid present is usually sulphuric, owing to the acid used in refining not being completely washed out of the oil. Its presence can be detected by shaking about one-fourth of a test-tubeful of oil with an equal quantity of warm distilled water in a test tube. The oil is poured off carefully and the water tested with neutral litmus paper, which in presence of acid is changed to red. If the litmus paper used were too blue, the acid might be all used up before the color changes; hence in this case it should be exposed to the fumes of hydrochloric acid until nearly neutral. A test should be made to be sure that the water is not acid. Not more than a faint reddening is allowable. The acid content should not exceed 0.3 per cent., calculated as sulphuric anhydride (SO_3).

Test for animal and vegetable oils in mineral oils. Put about an inch of the oil into each of two test tubes. To one of these add two pieces of metallic sodium as large as half a pea, and to the other a similar quantity of sodium hydrate (caustic soda). Extreme care should be taken in handling these substances as the metallic sodium takes fire if wet, forming caustic soda which vigorously attacks the skin and clothing. If any gets upon either the skin or clothing, wash it off with water and dilute muriatic acid and then remove the acid with water.

Heat the test tubes in an oil bath to a temperature of about 445° F. in case the oil is light colored, and 480° F. if it is dark colored. In case fatty oil is present, the contents of one or both of the tubes show a foam as of soap bubbles on the surface, and solidify to a jelly of greater or less consistency, according to the amount of fatty oil present.

The oil bath is in an iron pot containing heavy cylinder oil, lard or cotton-seed oil deep enough to cover the oil surface in the test tubes.

Detection of "oil-thickener" or "oil-pulp." This is usually an oleate of aluminum, a soap, which is dissolved in the oil to increase its viscosity at ordinary temperatures, but has little effect on the oil at the temperature at which it is used. It may be detected by diluting the oil with an equal quantity of naphtha and adding about 15 drops of a saturated solution of stick phosphoric acid in absolute (100 per cent.) alcohol. The mixture is allowed to stand and the formation of a flocculent precipitate indicates the presence of soap.

As showing the extent to which it affects the viscosity, a sample of oil containing it would not flow from the viscosimeter at 70° F., required 1167 seconds at 85° and 181 seconds at 110°.

Evaporation Test. This is often applied to light oils, like spindle and loom oils. It measures the loss sustained by an oil when exposed on a bearing. It requires a delicate analytical balance, sensitive to a thousandth of a grain, to detect the loss, as the amount of oil used is small (200 milligrams or 3.1 grains). The amount of loss should not exceed 4 per cent. The test is important to the mill owner, as it represents the amount of oil that stays on the bearing and serves its purpose. It is of even greater importance to the insurance underwriter, as it measures the amount of volatile inflammable matter passing into the atmosphere and liable to cause a fire. This actually happened in a spinning mill in Maine. The oil contained, however, 25 per cent. of volatile matter; that is, the evaporation test was 25 per cent. As a result of an investigation undertaken by the insurance companies, all oils of this type were driven out of use within a year.

In making this test the oil is exposed upon annular disks of filter-paper 1⅝ inches outside diameter, with the hole ⅝ inch in diameter, which have been drying for several days in a sulphuric acid desiccator contained in a flat watch-glass. The watch-glass and paper are weighed to tenths of a milligram, and about 0.2 gram of oil brought upon it by dropping from a rod, and accurately weighed. The watch-glass is now placed in an air-bath, the temperature of which remains nearly constant at 140° to 150° F. and heated for eight hours. It is then cooled and reweighed, the loss being figured in per cent. No oil should be passed which gives an evaporation of more than 4 per cent.

Friction Test. By this is meant the determination of the amount of power required to overcome the resistance of an oil when applied to a bearing. The oil is tested under ideal conditions with a shaft and boxes as nearly perfect as mechanical skill can make them, with the feed of oil, the temperature and pressure on the bearing even, regular and under complete control.

The small Thurston machine, Figs. 9 and 10, will give an idea of the principle and construction. It consists of the

testing-shaft or journal F, 1½ in. long by 1¼ in. in diameter, and the bronze bearings GG¹, the pressure of which on the shaft can be regulated by the coil spring. The amount of pressure is shown by the index M. A thermometer in Q indicates the temperature of the bearing. The journal is
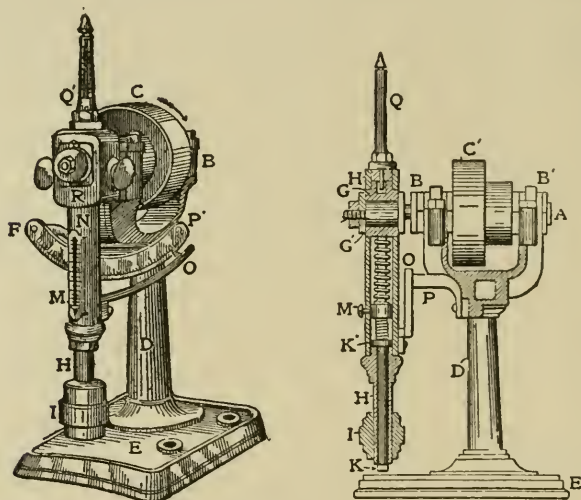
Figs. 9 and 10—THURSTON MACHINE.

rotated by means of the step-pulley C in the direction of the arrow; this causes a displacement of the pendulum GK, containing the spring J along the arc PP¹.

The amount of displacement along this arc measures the friction of the oil, being large with great friction and small with good lubricants. The arc is so graduated that, dividing the reading by the pressure shown by the index M, the coefficient of friction is given. This machine is designed for testing the lighter oils. A larger size of this machine is made with a journal 3¼ in. in diameter and 7 in. long for heavy lubricants and railroad work.

The writer is inclined to question the value of the friction test for practical purposes. He believes that equally good or better results can be obtained by comparing the flash, fire, gravity, and viscosity tests of the oil in question with like tests of an oil that has given satisfactory results

in practice. This is true only of oils coming from the same field or part of the country. Texas, Ohio and Pennsylvania oils, or oils having an asphaltic base, cannot be compared with those having a paraffin base, nor those carrying sulphur with those not carrying sulphur.

Testing of Burning Oils.

The chief tests to be applied to this class of oils are the flash, fire, specific gravity and sulphuric acid test.

In making the Flash Test, three different types of testers are used: (1) the open tester, in which the cup containing the oil is not covered or closed, but is freely open to the air; (2) the covered or New York State tester, in which the cup is covered with a glass cover containing two holes; and (3) the closed tester in which the oil is heated in a tightly closed cup which is opened momentarily for the introduction of the testing flame.

The New York State tester consists of a copper oil cup,

Fig. 11, holding about 10 ounces, the quantity usually contained in a lamp, and heated in a water-bath by a small Bunsen flame. The cup is provided with a glass cover, carrying a thermometer and there is an opening for the insertion of a small gas flame ¼ inch in length.

The regulations of the New York State Board of Health stipulate that the test shall be applied according to the following directions:

Remove the oil-cup and fill the water-bath with cold water up to the mark inside. Replace the oil-cup and pour in enough oil to fill it to within one-eighth of an inch of the flange, joining the cup and the vapor-chamber above. Care must be taken that the oil does not flow over the flange. Remove all air-bubbles with a piece of dry paper. Place the glass cover on the oil-cup and so adjust the thermometer that its bulb shall be just covered by the oil.

If an alcohol lamp is employed for heating the water-bath, the wick should be carefully trimmed and adjusted to a small flame. A small Bunsen burner may be used in place of the lamp. The rate of heating should be about two degrees per minute, and in no case exceed three degrees.

As a flash-torch, a small gas jet one-quarter of an inch in length should be employed. When gas is not at hand employ a piece of waxed linen twine. The flame in this case, however, should be small.

When the temperature of the oil has reached 85 degrees F., the tests should commence. Insert the torch in the opening at such an angle as to clear the cover and to a distance about half-way between the oil and the cover. The motion should be steady and uniform, rapid and without any pause. This should be repeated at every two degrees' rise of the thermometer until the thermometer has reached 95 degrees, when the lamp should be removed and the testings should be made for each degree of temperature until 100 degrees is reached. After this the lamp may be replaced if necessary and the testings continued for each two degrees.

The appearance of a slight bluish flame passing entirely over the surface of the oil shows that the flashing-point has been reached.

In every case note the temperature of the oil before introducing the torch. The flame of the torch must not come in contact with the oil.

The water-bath should be filled with cold water for each separate test, and the oil from a previous test carefully wiped from the oil-cup.

In making the flash test it should be borne in mind that liberating the vapor quickly from the oil lowers the flash-point. This may be caused by: (1) rapid heating; (2) a large and shallow cup from which the evaporation takes place quickly; (3) a large quantity of oil used for the test; and (4) a large testing flame or one too frequently or closely applied.

The results obtained with this apparatus are about 5° to 8° lower than those obtained with open cups. This cup reproduces more closely than any other the conditions prevailing when burning the oil in lamps. The tester, like a lamp, is not freely open to the air, preventing the escape of volatile vapors. This escape takes place with open cups and consequently the results obtained with them are higher.

The Fire Test is made by raising the cover above the cup and continuing to heat the oil until it gives off vapors which burn continuously when ignited. It is usually 15° to 25° higher than the flash-point.

In choosing a burning oil, one of a high flash-point rather than one of a high fire-point should be selected, as the flash not the fire-point determines the safety of the oil. Oils having a high flash test are sure to have a high fire test; but those of a high fire test may or may not have a high flash test. That is, in making the first test, no attention is paid to the flash test, and the dangerous volatile constituents of the oil (naphtha) escape detection, being driven off. This was well illustrated in a sample of fuel oil sent to the writer for test. The flash-point was 60° F. and the fire-point 143°. Had the fire-point alone been considered it would have been regarded as a safe oil, whereas the flash-point, 60° F., showed it to be dangerous. Too much stress, therefore, cannot be laid on the flash test, which should be at least 110° F. (or better, 120°), remembering that a safe oil makes safe lamps. Professor Engler states that no lamp should be used which heats the oil more than 10° F. above the surrounding atmosphere.

The **Specific Gravity** of burning oils is determined exactly as in the case of lubricating oils.

The **Sulphuric Acid Test** shows the degree to which an oil is refined; that is, the extent to which the tarry and ill-smelling products in the oil formed during the process of distillation have been removed. It is made by shaking 100 parts, by weight, of the oil with 40 parts of sulphuric acid of 1.73 sp. gr. for two minutes, and noting the color of the acid layers. A suitably refined oil should give little or no color.

Tests for Animal and Vegetable Oils.

When examining an unknown oil the analyst should ascertain all possible facts about it: its cost, its source, and the use for which it is intended. There is unfortunately no such number cf specific tests for the various oils as there are for the various metals. While it is easy to say positively that a certain metal is present or absent, the same cannot be said of many of the oils. We can be practically sure of the presence of cotton-seed, sesamé, rosin and mineral oils, and reasonably certain of peanut, rape, castor, and sperm, but can have only suspicions as to the presence or absence of most of the others.

The fact that crops vary in quality from year to year, cannot but have its influence upon the quality of vegetable oils produced. Whereas, in the case of an inorganic compound, like soda ash, we can require that it must contain 58 per cent. of oxide of sodium, with less than 1 per cent. variation either way, we cannot prescribe such definite specifications for oils, for the reason just stated, namely, the variation in genuine oils, on account of the change due to the seasons, wet or dry, cold or hot, or the variety of the plant or tree—there are 300 varieties of olive trees in Italy alone.

These influences change the characteristics, like the specific gravity, Maumené figure, etc., which are our guides for determining the adulteration of an oil. For example, the Maumené figure for olive oil varies from 35° to 47° C.; consequently, if we find a figure of 44° there are three possibilities: (1) that the oil is genuine; (2) that it is an oil originally of a figure of 47°, which has been adulterated with an oil of lower Maumené figure; or (3) that the original figuré

was 41° and it has been adulterated with an oil of higher Maumené figure. As to which of these is correct, we must be guided by other "constants" and special tests. There is a variation of 12/44 or 27 per cent. in these characteristic "constants"; consequently, the determination of the percentage of one oil in another may not be accurate within about 14 per cent. On the other hand, it should be noted that the sensitiveness of chemical methods permits the carrying out of the processes for the determination of these "constants" within at least 1 per cent. or even less.

Considering the items of cost, source and use, the cost, compared with current prices, will give an idea of the kind of oil if it is uncompounded. It is not usual to find an expensive oil mixed with one of lower price, unless in certain lubricants (cylinder oils). The source or kind of an oil will give an idea of the possible adulterants, and also of the tests and constants to which it should respond. If the source or kind of oil is not known, the use to which the oil is to be put is of material help in determining its composition. For example, the paint oils are linseed, menhaden ("pogy"), and, in some cases, corn. The currying oils are neatsfoot and "cod." The burning oils are lard, sperm, and rape. The textile oils are olive, oleine, elaine, red, lard, neatsfoot and mineral. The cutting oils are lard and soluble oils.

Physical Tests. The smell of an oil reveals to the expert much regarding its composition. If the amateur will take the trouble to make a collection of samples of genuine oils for comparison, he will find them very valuable in this connection. The odor is best taken by warming the oil in a small beaker or by rubbing a small quantity of the oil between the thumb and finger and smelling them. Marine animal oils are readily detected by their strong, fishy odor, while neatsfoot, tallow, lard, olive, rosin, and linseed oils have each a well-marked and easily distinguishable odor. Many of the statements just made apply with equal force to the taste of oils, rape oil having a harsh, unpleasant taste, and whale oil a nutty flavor.   ,

The color of an oil is not to be relied upon for identifica-

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tion, as oils may be colored reddish or greenish by the oleates of iron or copper. The "bloom" fluorescence or peculiar bluish or greenish streak seen on the sides of a vial containing mineral oil, is proof positive of the presence of a hydrocarbon or petroleum oil. This can be further shown by putting a few drops of the oil on a piece of hard rubber or other black surface and observing the bluish color.

Specific Gravity. This is determined with a hydrometer in the same way as with mineral oils. If the instrument is graduated in Baumé degrees only, the reading should be converted into specific gravity referred to water, as that is the way in which the animal and vegetable oils are designated. Care should be taken to note the temperature of the oil, which should be 60° F., as in the case of petroleum, and for every degree Fahrenheit above 60° add 0.00035 to the observed specific gravity:

Ex.—The hydrometer shows a reading of 23.75° Be. at 70° F. Find the specific gravity of the oil in question at 60° F. Table 1 shows that 23° Be. = 0.9150 and 24° = 0.9090, a difference of 0.0060 for 1° Be.; 0.75° Be. (the excess above 23° × 0.006 = 0.0045; .9150 — .0045 = .9105. That is: 23.75° Be. = 0.9105 sp. gr. For every degree Fahrenheit above 60, 0.00035 is to be added, or (.00035 × 10) .0035 for 70°. Then .9105 + .0035 = .9140, the specific gravity of the oil at 60° F.

The fact that the hotter an oil is the lighter it is, should not be forgotten.

Valenta Test. This depends upon the solubility of the various oils in glacial acetic acid. Glacial acetic acid is so strong that it freezes at 62° F. and boils at 244° F. Care should be used not to let it come in contact with the body, as it blisters severely.

A test tube is filled with the oil to the depth of about one inch, the exact height being marked by the thumb. An equal quantity of glacial acetic acid is poured in until the acid reaches the point indicated by the thumb. A light thermometer is placed in the tube, which is heated until the oil dissolves, which is shown by the liquid becoming homogeneous. The tube is now allowed to cool, and the point noted at which the oil begins to become thoroughly turbid. It is slightly warmed again until clear and the cooling is repeated. The readings should coincide within half a degree. Castor

oil is soluble at the ordinary temperature, while rape seed is usually insoluble at the boiling-point of the acid. The temperatures at which some oils become turbid are shown in Table 3.

Elaidin Test. This test depends on the fact that certain oils, rich in olein, like lard and neatsfoot, are changed by nitrous acid into a solid body, having the same composition, elaidin. It serves to distinguish between the non-drying, semi-drying, and drying oils. When submitted to this test, the non-drying oils usually form a solid cake, so solid that the vessel and contents can be lifted by the rod congealed in the cake of elaidin. The semi-drying oils form a more or less pasty mass, while the drying oils form a liquid mass with clots floating in it.

The test is performed as follows: 77 grains of the oil is weighed out into a cordial glass (a small goblet about three inches high) on the horn pan scales, and 108 grains nitric acid of 1.34 sp. gr. weighed into it. The glass is immersed in a pan of iced water, at 50° to 60° F. to within half an inch of the top. After about ten minutes two pieces of copper wire, No. 15, B. & S. gage, ¾-inch long, are wet in water and dropped in, and the oil and acid stirred together with a short glass rod, with an up-and-down as well as a rotary movement, so as to mix the oil, acid, and evolved gas thoroughly. When the wire has dissolved, add two more pieces and allow to stand two hours. This should furnish gas enough, if the liquid has been kept cool and the stirring has been thorough. At the end of the first hour pure lard will usually show flakes of a wax-like appearance, and upon standing without disturbance for another hour at the same temperature, the oil will have changed to a hard, solid, white cake. Most of the fish and seed oils yield a pasty or buttery mass, separating from a fluid portion, whereas olive, lard, sperm, and sometimes neatsfoot oil, yield a solid cake.

To make sure of the manipulation, a test should be made at the same time and in the same way with an oil of undoubted purity, lard oil for example. If a hard cake is obtained with the pure oil and a buttery mass with the oil under examination, it is very good evidence that the latter is either a seed oil or an olive, lard or sperm oil, adulterated with a seed or mineral oil.

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The **Maumené Test**, or heating test with sulphric acid, is one of the most important tests to determine the variety or kind of an oil; it has the advantage of requiring no complicated apparatus and is simple in execution. The underlying principle is that when oils are mixed with strong sulphuric acid, heat is produced and the quantity of heat so produced is characteristic of the various oils.

The apparatus required consists of a rather tall and narrow beaker, holding about 5 ounces (150 cc.), which is packed in a tin can, agate-ware cup or larger beaker, with dry cotton waste or hair felt, the packing being perhaps an inch thick. A light thermometer graduated from 0° to 150° or 200° C., a tall 10-cc. graduate and pair of horn pan scales complete the outfit.

The test is conducted as follows: The beaker is taken out from its packing—disturbing it as little as possible, weighed on the scales and 50 grams of oil weighed into it, to within two drops, the beaker replaced in its jacket, the thermometer inserted in the oil, and its temperature noted. Ten cubic centimeters of strong sulphuric acid is gradually run into the oil, which is stirred at the same time with the thermometer, and the graduate allowed to drain about five seconds—that is, while one counts ten. The stirring is continued until no further increase in temperature is noted. The highest point at which the thermometer remains constant for any appreciable time is observed, and the difference between this and the original temperature of the oil is the *rise of temperature*.

The mixture of oil and acid is thrown on the ash heap, and thermometer and beaker are carefully wiped free of oil with cotton waste, the jacket is allowed to cool to the original temperature, and the apparatus is again ready for use. A duplicate test should always be made and the results should agree within 2 or 3 per cent.; that is, with a rise of 40° C., the results of the two experiments should differ by only one degree. Since the rise of temperature varies with the strength of the acid the experiment should be repeated to secure uniformity, using water instead of oil, and the rise of temperature here obtained, used to divide the rise of temperature with the oil, and the result multiplied by one hundred. This is called the "specific temperature reaction." The

acid used should be the strongest obtainable and should show a specific gravity of 1.84. Fuming sulphuric acid should not be used.

In case the test is to be applied to a drying or semi-drying oil, it should be diluted with an equal weight of petroleum oil and then thoroughly mixed. The rise of temperature is in this case the rise of temperature of the mixture, minus half the rise of temperature of fifty grams of mineral oil, multiplied by two.

For concordant results the conditions should be the same, and the same apparatus should be used. The percentage of one oil in a mixture of two oils can be found by the following formula:

Let $x =$ percentage of the one oil, and y of the other; further, $m =$ Maumené value of pure oil x, and n of pure oil y, and 1 of oil under examination, then

$$x = [100 \ (1-n)] \div (m-n)$$

Suppose we have an olive oil adulterated with cottonseed. The sample in question has a Maumené figure of 60. We see from Table 3 that cottonseed oil has a Maumené figure of 76 and olive oil one of 35. Then, substituting in the formula, $x = (60-35) \div (76-35) = 61\%$. That is, there is about 60 per cent. of cottonseed oil in the olive oil. As with other oils, it is advisable to make a test with an oil of known purity.

Halphen's Test for Cottonseed Oil. This test depends upon the fact that the oil contains a fatty acid, which combines with sulphur, giving a colored compound. The apparatus needed is a large test tube seven or eight inches long by one inch in diameter, fitted with a tube $\frac{3}{8}$ inch in diameter and about five or six feet long to serve as a condenser for the alcohol which is used in the test. To join or fit the long tube to the test tube, soften a good cork that fits the test tube, by rolling it under a board on the bench. With a 6-inch or 7-inch round-file, bore a hole through the cork from the small end, file this with larger round-files until the long tube fits snugly into the cork. Before trying the tube in the cork, round the sharp edges with a file, otherwise they will cut the cork and make a poor fit. If the tube is wet, it will slip or twist into the cork much better. Besides this, an

agate-ware cup holding brine, and means of heating it and a water-bath are required. The chemicals or reagents needed are amyl alcohol (fusel oil) and a 1½ per cent. solution of sulphur in carbon bisulphide. This should not be opened near a fire or flame, as it is very inflammable.

To make the test, about two or three teaspoonfuls (10-15cc.) of the melted fat or oil (the exact quantity makes no difference) are heated with an equal volume of the amyl alcohol and of the carbon bisulphide solution of sulphur, with occasional shaking, in the water-bath and, after the violent boiling has ceased, in the brine bath at about 220°-230° F. for forty-five minutes to three hours, according to the quantity of cottonseed oil present, the tube being occasionally removed and shaken. As little as 1 per cent. will give a crimson-wine coloration in twenty minutes. If the mixture is heated too long, a misleading brownish red color due to burning is produced.

Test for Unsaponifiable Oils in Animal or Vegetable Fats and Oils. This test depends upon the fact that when a soap solution containing unsaponified oil is diluted with water, it is precipitated, causing an opalescence or turbidity. Six or eight drops of oil are boiled two minutes in a test-tube with a teaspoonful of 3 per cent. alcoholic-potash solution. This is made by dissolving caustic potash (take care!) in ordinary alcohol or wood spirits. The potash makes soap of the oil and to this soap solution distilled water is gradually added (½ to 15 cc.), and one notices whether the solution remains clear or whether a turbidity appears which clears on the addition of more water. Even 1 per cent. of mineral oil may be detected in this way.

There are two other tests which are applied to these oils which require considerable experience and a number of reagents that can be prepared only by a skilled chemist. As these are sometimes referred to in oil analysis they will be defined here. These tests are the **Saponification Number and Iodine Value.** By the saponification number or value is meant the number of parts by weight of potassium hydrate (KOH), caustic potash, necessary to saponify 1000 parts of the oil. This is nearly the same for many oils, averaging 193. Rape has a number of 178; and sperm, 124-145. The number is mainly of value in detecting the adulteration of animal or

vegetable oils with petroleum or rosin oils which are not saponifiable.

By the iodine number or value is understood the number of parts by weight of iodine absorbed by 1000 parts of oil; this varies from 176 with linseed, to 8 with cocoanut oil. This can be used the same as the Maumené figure for calculating the adulteration in an oil.

Spontaneous Combustion Test.

The liability to gum on exposure to the air can best be determined with the apparatus which enables a current of
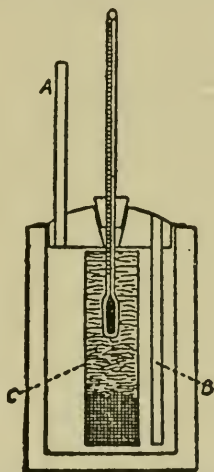
Fig. 12—MACKEY'S APPARATUS.

air to be drawn over the oil, which is exposed in a thin layer at a temperature of 400° F. for two hours. The extent to which the oil gums is measured by noting the percentage increase in its viscosity. An oil showing an increase of over 8 per cent. is liable to give trouble. This method has been tested by Richardson and Jaffe and also by the author and found to give reliable results.

Finally in making out specifications, certain mechanical details should not be overlooked. The barrels should be clean and the oil should be free from specks, dirt, stearine,

glue or anything likely to clog the lubricators that may be used; the oil should be free from tar (still bottoms) as shown by the gasoline test, and if compounded should be composed of oils that mix perfectly.

Mackey's apparatus, Fig. 12, consists of a cylindrical copper water-bath 7 in. high and 4 in. inside diameter, surrounded with a half-inch water-jacket. The cover is packed with asbestos and carries the draft tubes A and B, ½ in. in diameter and 6 in. long, which cause a current of air to be sucked down B and up A, thus ensuring a circulation of air in the apparatus. C is a cylinder made of 24-mesh wire gauze 6 in. high and 1½ in. in diameter, supported upon a projection from the bottom of the bath. A thermometer projects into the center of the cylinder. If a metal condenser is connected to the water-bath the latter can be used indefinitely without refilling and without danger of burning out.

One hundred and eight grains of ordinary bleached cotton wadding are weighed out in a porcelain dish or on a watch-glass, and 216 grains of the oil to be tested poured upon the cotton and thoroughly worked into it, care being taken to replace any oil that is lost. The cotton is then placed in the cylinder, packed about the thermometer so that it occupies the upper 4½ in. of the cylinder, and put into the boiling water-bath. At the end of an hour, the bath having been kept in active ebullition, the temperature is read. Any oil which shows a temperature exceeding 100° C. in one hour or 200° C. in two hours should be regarded as a dangerous oil liable to produce spontaneous combustion. The following tables show the results obtained in using this apparatus:

Oil	1 hr.	Temperature °C. in 1½ hrs.	1½ hrs.
Olive (neutral)	97-98	100	101
Cotton-seed	112-128	177-242	194-282
Elaine	98-103	101-115	102-191
Olive fatty oils	102-114	......	196

Other values obtained were:

Oil	Temp. °C.	Time Minutes	Iodine No.	Free Acid %
Olive	234	130	85.4	5.3
Lard	234	75	75.2	Trace
Oleic Acid	158	188	60.5	
Cotton-seed	234	70	108.9	Neutral
Linseed	234	65	168.1	Neutral
25° Paraffin	97	135	16.2	

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Besides being used for testing oils this apparatus can be applied to testing other materials, oily waste, sawdust, or any mixture suspected of causing spontaneous combustion.

The results of the greatest practical value obtained in the use of this apparatus have been: (a) determining the cause of fires; (b) second, determining the degree of safety of the various oils used in manufacturing. Mineral oil, as is well known, is not liable to spontaneous combustion; and a certain percentage of animal or vegetable oil may be added to mineral oil without materially increasing the danger under ordinary circumstances. This percentage varies according to the oil. With neatsfoot and first quality lard oil some 50 to 60 per cent. may be used. With cotton-seed not over 25 per cent. is allowable. The claims so often made for so-called "safe" oils, said to have been changed by special and secret processes of refining so as to be no longer dangerous, are easily exposed by this test.

General Considerations

According to the results of the viscosity and friction tests, the least viscous oil is to be given the preference. It should be borne in mind, however, that the heat of the journal diminishes the viscosity. For example, at 60° F., if the viscosity of sperm oil be taken as 100, that of 25° paraffin oil is 123; at 100° F. the latter has diminished to 110, and at 250° F. the two are practically equal. On account of this change in temperature, as well as the irregularities of the journals, of the feed and of pressure, a too thinly fluid oil must not be chosen.

The following considerations will aid in the selection of a suitable oil.

1. The flashing point of the oil should be above 300° F.

2. The oil should have an evaporation test of less than 5 per cent.

3. On general principles the most fluid oil that will stay in place should be used.

4. The best oil is that which possesses the greatest adhesion and least cohesion. This condition is fulfilled first, by

fine mineral oils, except at high temperatures; second, sperm; third, neatsfoot; fourth, lard.

5. For light pressures and high speeds, mineral oils of specific gravity 30.5° Bé., flash point 360° F., sperm, olive, and rape (Thurston adds also cotton-seed) should be employed.

6. For ordinary machinery, mineral oils of specific gravity 25° to 29° Bé., flash point 400° to 450° F., lard, whale, neat's-foot, and tallow, also heavy vegetable oils should be used.

7. For cylinder oils, mineral oils of specific gravity 27° Bé., flash point 550° F., alone and with small percentages (1 to 7) of animal or vegetable oils are employed; the latter are degras, tallow, linseed, cotton-seed, and blown rape.

The above specifications apply to oils of paraffin base; the asphaltic base oils are about 7° Bé. heavier, flash lower and are much more viscous than the corresponding paraffin base oils; they also lose their viscosity more rapidly except at high temperatures, when the reverse holds true. Consequently when these oils are specified, their viscosity should be from 25 to 50, or in some cases, even 75 per cent. greater.

8. For watches and clocks, clarified sperm, jaw, and "melon" oils should be employed.

9. For heavy pressure and slow speed, lard, tallow, and other greases, either by themselves or mixed with graphite and soapstone, should be used.

10. For very heavy pressure, solid lubricants, as graphite and soapstone, are employed.

11. To resist cold, as, for example, for lubricating air-driven rock-drills, kerosene has been used.

12. The oil should contain no acid to corrode the shaft or journal. The German railroads permit no more than 0.1 to 0.3 per cent. of acids, calculated as sulphuric anhydride, in their oils.

In addition to the conditions outlined in considerations 1 to 12, the way and manner in which the oil is applied, or the "feed," influences the choice. The various feeds may be divided into forced, gravity, ring or wick, splash, flooded bear-

Table 1. Comparison of Specific Gravity with Baumé Degrees.
(Lighter than water.)

Baumé	Sp. Gr.	Baumé	Sp. Gr.
10	1.000	29	0.881
12	0.986	30	0.875
14	0.972	35	0.848
16	0.959	40	0.823
18	0.946	45	0.800
20	0.933	50	0.778
21	0.927	55	0.757
22	0.921	60	0.737
23	0.915	65	0.718
24	0.909	70	0.700
25	0.903	75	0.683
26	0.897	80	0.666
27	0.892	85	0.651
28	0.886	90	0.636

The specific gravity can in general be found by the formula $140 \div (30 + B°)$. B° represents the reading Bé. at 60° F.

Table 2. Specific Gravity, Degrees Baumé, Weight per Gallon and per Cubic Foot of Certain Oils.

Oils	Sp. Gr. 60° F.	Degrees B.	Lb. per Gal.	Lb. per Cu. ft.
Castor	0.961	15.66	8.01	60.06
Cotton seed	.922	21.83	7.68	57.62
Horse	.919	22.17	7.66	57.44
Lard	.915	23.00	7.62	57.14
Linseed	.934	19.87	7.79	58.37
Neat's-foot	.915	23.00	7.62	57.14
Olive	.916	22.80	7.63	57.25
Rape	.916	22.80	7.63	57.25
Sperm	.880	29.00	7.34	55.00
Tallow	.916	22.80	7.63	57.25
Turpentine	.866	31.60	7.22	54.12
Whale	.927	21.00	7.72	57.93
Water	1.000	10.00	8.33	62.50

Table 3. Tests of Certain Oils.

	Viscosity				
	Doolittle	Saybolt	Flash	Valenta	Maumene
Castor	viscid	132[1]	345	20	47
Colza	see Rape	....	....	....	....
Cottonseed	82.5	210[2]	582	90-110	76
Horse	....	....	....	54-80	52
Lard	82.8	215	530-600	54-98	41
Linseed	80.0	200[2]	525	57-79	111
Neatsfoot	83.7	250	440	62-75	42
Olive	66	68[2]	450	85-111	35
Rape	86.5	350[2]	530	Insoluble	55
Sperm	73.5	102	430-480	Insoluble	46
Tallow	75.0	125[2]	560	71-75	35
Turpentine	....	....	119-125	....	....

[1] At 140 deg. F.   [2] Calculated from Doolittle reading.

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ing and hand feed, or combinations of these. Of these the forced, gravity, and ring or wick, are economical, of high efficiency, collect little dirt, and in the case of the first two, furnish strained oil and use a light or medium-bodied oil; the same holds true of the flooded bearing, except as regards the efficiency of the recovery of the oil. The chief disadvantage of the splash feed is that any dirt and wear from the bearings are not separated from the oil. Hand feeding is most wasteful and inefficient, depending upon the efficiency of the individual. Forced feed is employed with high speed and bearing pressures; it uses a somewhat more viscous oil—particularly with automobiles, than the other types of feed.

Wear and Tear of Oils. The question is often asked whether oils "wear out." This continues the Southwick conception of the ball bearing and implies that the balls or molecules break or wear out. Carpenter and Sawdon showed that the gravity and viscosity of the oils in circulating systems increased, but the actual friction test was slightly lower at low pressures, and a trifle higher at high pressures. With automobile lubrication, the dilution of the oil by the gasoline residues causes it to become thinner; consequently fresh oil should be added to a circulating system to keep this viscosity practically constant.